Harris County
Public Health
ENVIRONMENTAL PUBLIC HEALTH

2021

Vulnerability Assessment Indicators

EXTREME HEAT AND HEALTH

CLIMATE PROGRAM

Table of Contents

Heat Index

Indicator Title: Heat Index

Indicator Description: Average maximum heat index from 2011-2016

Assessment Group: Exposure

Summary of evidence for Climate and Health:

The heat index is a combination of temperature and humidity. Humidity is important factor because it inhibits the body's ability to sweat, which is a natural cooling mechanism. Exposure to high temperatures and high humidity can cause numerous heat-related illnesses such as heat cramps, heat exhaustion, heat stroke and death. In recent years, extreme heat has been a leading cause of weather-related deaths in the United Stated (U.S. Environmental Protection Agency [EPA] & U.S. Centers for Disease Control and Prevention [CDC], 2016). Heat-related mortality rates in Texas were associated with afternoon high temperatures and duration of extreme heat events (Greenberg et al., 1983). Extreme heat can also exacerbate pre-existing conditions, in particular cardiovascular, renal, and respiratory conditions (Sarofirm et al., 2016). A study of the 2011 Heatwave in Harris County, Texas found an increased risk for emergency department visits (Zhang et al., 2015). This research is consistent with similar studies conducted after Chicago and California heatwaves (Zhang et al., 2015). Harris County and southeast Texas are expected to see higher temperatures, longer heat waves, and higher night-time temperatures in the future (Stoner & Hayhoe, 2020). These changes can increase exposure and overall health outcomes, especially for the most at-risk who may not have the ability to reduce their exposure or access to adaptive measures such as air conditioning.

What is the indicator: Average maximum heat index from 2011-2016

Data Source and methodology: This data from the National Center for Atmospheric Research (NCAR) depicts the 6-year average (2011-2016) maximum heat index during summer months (June, July, August) for each Census Tract in Harris County, TX. NWS Heat Index daily heat index values were estimated in 1km x 1km grids from 2011 to 2016 using HRLDAS. To get specific estimates for each Census Tract in our study area, the 1km estimate closest to the centroid of each tract was used for extracting the meteorological data.

Limitations: This data only accounts for 6 years of temperature and humidity. Because climate change typically considers changes over long periods of time, having an average from a greater number of years would be beneficial. Three census tracts (48201543100, 48201253300, and 48201254700) were missing heat indexes

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Night-time Cooling

Indicator Title: Night-time Cooling

Indicator Description: Change in temperature that happens over-night.

Assessment Group: Exposure

Summary of evidence for Climate and Health: Several studies across the U.S. have found a strong correlation between minimum night-time temperatures and excess mortality (Thomas et al.,2020). High temperatures at night between extreme heat days has been shown to significantly increase the risk of mortality. The same study, conducted in Hong Kong, found that excess mortality from extreme heat events lagged for up to 5 days (Wang et al., 2019) Cooler temperatures at night give the body a chance to recuperate from daytime exposures, but as temperatures increase at night there is less opportunity for the body recover. New research indicates that cloud cover and other meteorological factors may contribute to night-time heat waves in the Northeast, Midwest, and Southwestern United States. (Thomas et al.,2020) Meteorological factors are not the only contributor to night-time temperatures. A study conducted in Phoenix found an increase in both daytime and nighttime temperatures in areas that were converted from agricultural or desert land to urban land use. However, the change in night-time temperatures was more substantial (Grossman-Clarke et al., 2010).

What is the indicator: Difference between evening and morning temperatures

Data Source and methodology: The original data sources are the morning and evening raster datasets from the H3AT: 2020 Heat mapping Campaign. The evening temperature was subtracted from the morning temperature and the resulting temperature difference was averaged by census tract. The original datasets are modeled 10 by 10-meter raster based on actual temperature measurements collected the day of the campaign. All temperatures are in degrees Fahrenheit. Information about the H3AT mapping campaign is available at https://www.h3at.org/ , while the data is available for download at https://osf.io/yqh5u/ .

Limitations: This dataset only provides nighttime cooling data for those areas that were mapped during the H3AT heat mapping campaign. This is just an estimated amount of cooling given that we did not capture the morning temperatures the day after the campaign.

References:

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Diabetes

Indicator Title: Diabetes

Indicator Description: Percentage of adults with diabetes

Assessment Group: Sensitivity

Summary of evidence for Climate and Health:

When it comes to extreme heat, certain pre-existing conditions are important to consider. The body's ability to cool depends on the cardiovascular, endocrine, urinary and integumentary systems. Conditions that affect these systems can inhibit the physiological processes for perspiration and subsequent cooling of the body (Gronlund, 2014). Diabetes, for example, impacts multiple systems that can affect heat-related health outcomes. Blood vessel and nerve damage are complications of diabetes and they can affect the body's ability to sweat and cool itself. Additionally, high blood sugar can cause more frequent urination, therefore people with diabetes may become dehydrated more quickly (CDC, 2020). Extreme heat can also impact insulin absorption. High environmental temperatures cause blood vessels to dilate leading to increased insulin absorption potentially causing low blood glucose or hypoglycemia (CDC, 2019; Al-Qaissi et al., 2019). For these reasons, people with diabetes may be more sensitive to extreme temperatures.

What is the indicator: Percentage of adults who have had a diabetes diagnosis

Data Source and methodology: These estimates come from the 2018 Health of Houston Survey by the University of Texas School of Public Health. https://sph.uth.edu/research/centers/ihp/#TID-e1bc0d84-d308-4213-9931-c667967d8c23-3. This data was provided at the PUMA level. PUMAs are larger than census tracts. Each census tract was assigned the value associated with the PUMA in which it is located.

Limitations: This data is at PUMA level and may not completely or accurately represent the percentage of diabetes at the census track level.

References

CDC. (2020). Managing Diabetes in the Heat. Retrieved November 23, 2020, from https://www.cdc.gov/diabetes/library/features/manage-diabetes-heat.html

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Al-Qaissi A, Papageorgiou M, Javed Z, Heise T, Rigby AS, Garrett AT, et al. (2019). Environmental effects of ambient temperature and relative humidity on insulin pharmacodynamics in adults with type 1 diabetes mellitus. *Diabetes Obes Metab* 21(3):569–574, PMID: 30311402, 10.1111/dom.13555.

Xu R, Zhao Q, Coelho MSZS, Saldiva PHN, Zoungas S, Huxley RR, Abramson MJ, Guo Y, Li S. (2019). Association between Heat Exposure and Hospitalization for Diabetes in Brazil during 2000-2015: A Nationwide Case-Crossover Study. *Environ Health Perspect.*127(11):117005. doi: 10.1289/EHP5688. Epub 2019 Nov 20. PMID: 31746643; PMCID: PMC6927500.

Cardiovascular Disease

Indicator Title: Cardiovascular Disease

Indicator Description: Percentage of adults with cardiovascular disease

Assessment Group: Sensitivity

Summary of evidence for climate and health:

The cardiovascular system is important during extreme heat events because of the role it plays in the body's cooling processes (Gronlund, 2014). Certain medications associated with heart conditions, such as beta blockers, can affect the body's ability to thermoregulate making people that take these medications more sensitive during extreme heat events (Sarofirm et al., 2016). Extreme heat can also exacerbate cardiovascular issues. Studies have shown an increase in emergency medical service calls, emergency room visits, and hospital admissions for cardiovascular complications to be associated with high summer temperatures (Ebi et al., 2018). In a recent study of heat-related mortality, exposure to high ambient temperatures contributed to 34% of ischemic heart disease deaths and 10% of hypertension deaths (Vaidyanathan et al., 2020). During extreme heat events, data has shown an increased risk of cardiovascular death in older adults (Sarofirm et al., 2016).

What is the indicator: Percentage of adults who have had a diagnosis of coronary heart disease

Data Source and methodology: These estimates come from the 2018 Health of Houston Survey by the University of Texas School of Public Health. https://sph.uth.edu/research/centers/ihp/#TID-e1bc0d84-d308-4213-9931-c667967d8c23-3. This data was provided at the PUMA level. PUMAs are larger than census tracts. Each census tract was assigned the value associated with the PUMA in which it is located.

Limitations: This data is at PUMA level and may not completely or accurately represent the percentage of cardiovascular disease at the census track level.

References

Ebi, K.L., J.M. Balbus, G. Luber, A. Bole, A. Crimmins, G. Glass, S. Saha, M.M. Shimamoto, J. Trtanj, and J.L. White-Newsome, (2018). Human Health. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 539–571. doi: 10.7930/NCA4.2018.CH14

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Respiratory Conditions

Indicator Title: Respiratory Conditions

Indicator Description: Percentage of adults with asthma and/or COPD

Assessment Group: Sensitivity

Summary of evidence for climate and health

Similar to cardiovascular disease, extreme heat can exacerbate respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD). Exposure to high temperatures for long periods of time has been associated with an increase in hospital admissions for various conditions, including respiratory issues (Sarofirm et al., 2016). High temperatures can impact air quality. Ozone and particulate matter concentrations can change during extreme heat events, which may contribute to the increases in respiratory issues when temperatures are high (Sarofirm et al., 2016). There have been studies that adjust for changes in air pollution and they do not account for all the increases in respiratory risks during hot weather. Pollen and mold are also impacted by high temperatures which could exacerbate asthma and other respiratory conditions (Anderson et al., 2013).

What is the indicator: Percentage of adults who have had an asthma and/or COPD diagnosis

Data Source and methodology: These estimates come from the 2018 Health of Houston Survey by the University of Texas School of Public Health. https://sph.uth.edu/research/centers/ihp/#TID-e1bc0d84-d308-4213-9931-c667967d8c23-3. The percentage estimates of Respiratory Disease were calculated as the sum of those who have ever had an Asthma diagnosis, a COPD diagnosis or both. This data was provided at the PUMA level. PUMAs are larger than census tracts. Each census tract was assigned the value associated with the PUMA in which it is located.

Limitations: This data is at PUMA level and may not completely or accurately represent the percentage of respiratory conditions at the census track level.

References

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Poverty

Indicator Title: Households Living on the Poverty Line

Indicator Description: Percentage of population living below the poverty line

Assessment Group: Sensitivity

Summary of evidence for climate and health

Studies have shown income and poverty to be associated with increased hospital admissions and heat-related mortality in the United States (Gronlund, 2014). Income and poverty influence heat related health outcomes in many ways. People living below the poverty line may not have the ability to pay for household air conditioning costs. Income can also impact decisions to seek medical care for heat-related illnesses or complications (Gronlund, 2014). Additionally, people living below the poverty line may live in neighborhoods where the neighborhood infrastructure and design contribute to the urban heat island effect. This can increase exposure to high temperatures during extreme heat events and increase the costs necessary to operate air conditioning, ergo compounding issues that increase the likelihood of negative heat-related health outcomes (Gamble et al., 2016).

What is the indicator: Percentage of population living below the poverty line

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percentage of families and people whose income in past 12 months is below the poverty level (DP03_0128PE)

Limitations

References

Gamble, J.L., J. Balbus, M. Berger, K. Bouye, V. Campbell, K. Chief, K. Conlon, A. Crimmins, B. Flanagan, C. Gonzalez-Maddux, E. Hallisey, S. Hutchins, L. Jantarasami, S. Khoury, M. Kiefer, J. Kolling, K. Lynn, A. Manangan, M. McDonald, R. Morello-Frosch, M.H. Redsteer, P. Sheffield, K. Thigpen Tart, J. Watson, K.P. Whyte, and A.F. Wolkin, 2016: Ch. 9: Populations of Concern. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 247–286. http://dx.doi.org/10.7930/J0Q81B0T

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Older Adults

Indicator Title: 65+ Years of Age

Indicator Description: Population greater than 65 years of age

Assessment Group: Sensitivity

Summary of evidence for climate and health:

There are multiple factors that make older populations vulnerable to high temperatures. Older populations are more likely to have underlying health conditions like respiratory and cardiovascular illnesses that can be exacerbated by extreme heat. Additionally, older populations are more likely to take medications that can affect urination and their ability to sweat, which in turn can impact the body's ability to cool and stay hydrated (Gamble et al., 2016).

Older individuals may live alone which is a concern especially if they are socially isolated. Without the support of family, friends and caregivers during extreme heat events older adults may have trouble obtaining essential items, accessing health care services, and difficulty evacuating. This support can be lifesaving. Social isolation has become even more of a concern during the Covid-19 Pandemic because social distancing measures and stay at home orders have added extra challenges.

A study of the 2011 Houston Heatwave found that people 65 years or older had an increase in emergency department visits more than any other age group (Zhang et al., 2015). In a recent study, persons aged 65 and older accounted for nearly 40% of all heat-related deaths and had the highest rate of heat-related deaths in the Unites States (Vaidyanathan et al., 2020).

What is the indicator: Percentage of population aged 65 years or older

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percentage of population 65 years or older (DP05_0024PE)

Limitations

References

Chien, L.-C., Guo, Y., & Zhang, K. (2016). Spatiotemporal analysis of heat and heat wave effects on elderly mortality in Texas, 2006–2011. *Science of the Total Environment*, *562*, 845–851. https://doi-org.hcpl.idm.oclc.org/10.1016/j.scitotenv.2016.04.042

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Vaidyanathan, A., Malilay, J., Schramm, P., & Saha, S. (2020). Heat-Related Deaths - United States, 2004-2018. *MMWR: Morbidity & Mortality Weekly Report*, *69*(24), 729–734. https://doi-org.hcpl.idm.oclc.org/10.15585/mmwr.mm6924a1

Infants and Young Children

Indicator Title: Less than 5 years of age

Indicator Description: Population less than 5 years of age

Assessment Group: Sensitivity

Summary of evidence for climate and health:

Children under the age of 5 are at a greater risk for heat-related illnesses due to physiology and dependency on caregivers. The body's thermoregulation processes are not fully developed in children under 5 and can impede sweating (Greenfield and Clingenpeel 2016). This may cause the body to become overheated more quickly. Children under 5 may not recognize the signs of heat-related illnesses or they may not be able to effectively communicate them to their caregiver (Greenfield and Clingenpeel 2016). In the past, children have been left unattended in places that increase their exposure, such as inside a hot vehicle. As temperatures inside the vehicle increase, children's body temperatures can rise quickly, putting them at risk for heatstroke and other heat-related illnesses. In the year 2018, there were 53 pediatric vehicular heat stroke deaths, which is the most deaths of this type in twenty years. While this may not seem like a lot, all of these deaths are preventable (NHTSA 2020). According to Noheatstroke.org, Texas had 7 vehicular heat stroke deaths in 2019 and all the deaths were children under the age of 4 years old (Null 2020).

What is the indicator: Percentage of population less than 5 years of age.

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percentage of population under 5 years old (DP05_0005PE)

Limitations:

References:

Greenfield, B. and J.M. Clingenpeel, *Pediatric Heat Related Illnesses*. Emergency Medicine, 2016.

National Highway Traffic Safety Administration. (2020, November 14). *Help! Too Many Children are Dying in Hot Cars*. Retrieved from https://www.nhtsa.gov/child-safety/ help-too-many-children-are-dying-hot-cars.

Null, J. (2020). Heatstroke Deaths of Children in Vehicles. Retrieved November 14, 2020, from https://www.noheatstroke.org/

Linguistic Barriers

Indicator Title: Limited English-speaking abilities

Indicator Description: Percent of population with limited English proficiency

Assessment Group: Sensitivity

Summary of evidence for climate and health

There are several reasons why linguistic barriers have been identified as a risk factor for heat-related illnesses (Uejio et al., 2011). People that speak limited English may not fully understand heat warnings or public health messaging. Heat warnings or emergency warnings are often only made in English, which can prohibit non-English speaking individuals from fully understanding the hazard and how to protect themselves (Gronlund et al., 2014). If a health emergency were to occur, language barriers can often delay medical care if healthcare providers are unable to communicate. A language barrier can feel isolating and similar to social isolation, it can hinder people from seeking help during extreme heat events or other emergencies (Hansen et al., 2014).

What is the indicator: Percentage of the population that speaks English less than well

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percent of the population greater than 5 years old that speaks English less than well (DP02_0113PE)

Limitations:

References:

Gronlund, C.J. Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: A Review. *Curr Epidemiol Rep* **1,** 165–173 (2014). https://doi.org/10.1007/s40471-014-0014-4

Hansen, A., et al., *Extreme heat and cultural and linguistic minorities in Australia: perceptions of stakeholders*. 2014. 14(1): p. 550.

Uejio CK, Wilhelmi OV, Golden JS, et al. Intra-urban societal vulnerability to extreme heat: The role of heat exposure and the built environment, socioeconomics, and neighborhood stability. Health & Place. 2011

Outdoor workers

Indicator Title: Outdoor workers

Indicator Description: Percent of employed population that work outdoors

Assessment Group: Sensitivity

Summary of evidence for climate and health:

Outdoor workers, like those that work in construction or agriculture, often have extended exposure to extreme heat and are therefore at higher risk of illness (OSHA). Outdoor farm workers in the United States are four times more likely to suffer from a heat-related illness compared to other non-agricultural workers. Between 2003-2008 construction workers had the highest percentage of heat-related mortalities in the U.S. (Xiang et al., 2014). These outdoor occupations often require higher levels of physical activity that can increase sweat production and lead to dehydration. The proper protective clothing and equipment often necessary for job safety can also make the body hotter and can reduce its ability to cool (Jacklitsch et al., 2016).

What is the indicator: Percentage of employed population that works outdoors

Data Source and methodology: Harris County ACS 2019 5 year subject table estimates by Census Tract , Calculated: (Farming, Fishing, Forestry Occupations [S2401_C01_030E] + Construction and Extraction Occupations [S2401_01_031E]) / Total employed population > 16 years [S2401_C01_001E] * 100

Limitations: The categories selected were chosen because these fields are likely to have a high percentage of outdoor workers. There may be outdoor occupations missed and similarly this could entail some workers that do not primarily work outside.

References:

Jacklitsch B, Williams WJ, Musolin K, Coca A, Kim J-H, Turner N., NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments. 2016. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 2016-106.

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Race and Ethnicity

Indicator Title: Population of Color

Indicator Description: Percent of population that identify as black, indigenous, people of color, and/or Hispanic.

Assessment Group: Sensitivity

Summary of evidence for climate and health

Some racial and ethnic groups have been historically disadvantaged leading to inequities in income, education, community infrastructure and health outcomes. Evidence of those inequities can be seen in heat-related morbidity and mortality. Race and ethnicity are related to extreme heat events in several ways (Gronlund et al., 2014). A study of the 1995 Chicago heatwave demonstrated that black people were more likely to die during a heat event compared to whites and Latinos. During the same Chicago Heatwave, heat-related emergency department visits increased among Asian, Pacific Islander, and Black populations (Kaiser et al., 2007). Similar to Chicago, a heatwave study in New York City also saw an increase in heat-related deaths among non-Latino blacks (Madrigano et al., 2015). Jesdale et al. found that Black, Hispanic, and Asian populations tend to live in areas with high amounts of impervious surfaces and limited tree canopy (2013). Impervious surfaces absorb and retain heat which hinders nighttime cooling and helps to create the urban heat island effect. Tree canopy provides shade and cooling. Due to these built environment qualities, the people living in these communities could have increased exposure to high temperatures.

What is the indicator: Percent of population that identify as black, indigenous, people of color, and/or Hispanic.

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract

Calculated: (Total Population [DP05_0033E] - Count NonHispanic White alone [DP05_0077E]) / Total Population [DP05-0033E] * 100

Limitations: For the purposes of this assessment the racial and ethnic groups identified were assumed to have equal vulnerability; however, there may be variation in the level of vulnerability among these different groups.

References

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Kaiser, R., et al., *The effect of the 1995 heat wave in Chicago on all-cause and cause-specific mortality*. Am J Public Health, 2007. 97 Suppl 1: p. S158-62.

Madrigano, J., et al., *A Case-Only Study of Vulnerability to Heat Wave-Related Mortality in New York City (2000-2011)*. Environ Health Perspect, 2015. 123(7): p. 672-8.

No Health Insurance

Indicator Title: No health insurance

Indicator Description: Percent of population without health insurance

Assessment Group: Sensitivity

Summary of evidence for climate and health: Health insurance is an important component to consider when thinking about any health outcomes that require medical care. Extreme heat can cause heat related illnesses that often require medical care. In other cities, extreme heat events have been associated with an increase in hospital admissions, emergency room visits, and emergency medical services calls. Studies have shown that populations without health insurance are less likely to seek health care, and if they do receive care will likely have the added stress of the health care costs (Freeman et al., 2008). Additionally, people without health insurance were less likely to receive care for critical issues compared to those with insurance (Fowler et al., 2010). Lack of health insurance may be more of a concern with increased unemployment due to the Coronavirus pandemic.

What is the indicator: Percent of population without health insurance

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percent of civilian noninstitutionalized population with no health insurance coverage (DP03_0099PE)

Limitations

References

Fowler RA, Noyahr L, Thornton D, et al. An Official American Thoracic Society Systematic Review: The Association between Health Insurance Status and Access, Care Delivery, and Outcomes for Patients Who Are Critically Ill. American Journal of Respiratory and Critical Care Medicine. 2010; 181: 1003-1011

Freeman JD, Kadiyala S, Bell JF, et al. The causal effect of health insurance on utilization and outcomes in adults: A systematic review of US studies. Med Care. 2008; 46(10): 1023-32.

Disability

Indicator Title: People with disabilities

Indicator Description: Percent of population with disability

Assessment Group: Sensitivity

Summary of evidence for climate and health:

People with physical and mental disabilities may face challenges prior to, during, and after extreme heat events that can make them more vulnerable to high temperatures. There are certain medications for mental health conditions that can make people more susceptible to extreme heat. Patients prescribed anticholinergics, anti-psychotics, or anxiolytics were more likely to have an emergency room visit during the 2003 heat wave in France (NCCEH, 2010). Additionally, extreme heat can exacerbate some mental health conditions. Similarly, people with visual or hearing impairments may not receive heat warnings if they are not presented in the correct format. During an extreme heat event, people with mobility constraints may need assistance with transportation to cooler spaces and people mental disabilities may need friends, family, or caregivers to watch for signs of heat-related illnesses (Gamble et al., 2016).

What is the indicator: Percent of population with a disability

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percent of total civilian noninstitutionalized population with a disability (DP02_0071PE)

Limitations:

References:

Gamble, J.L., J. Balbus, M. Berger, K. Bouye, V. Campbell, K. Chief, K. Conlon, A. Crimmins, B. Flanagan, C. Gonzalez-Maddux, E. Hallisey, S. Hutchins, L. Jantarasami, S. Khoury, M. Kiefer, J. Kolling, K. Lynn, A. Manangan, M. McDonald, R. Morello-Frosch, M.H. Redsteer, P. Sheffield, K. Thigpen Tart, J. Watson, K.P. Whyte, and A.F. Wolkin, 2016: Ch. 9: Populations of Concern. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 247–286. http://dx.doi.org/10.7930/J0Q81B0T

National Collaborating Centre for Environmental Health, Drugs. 2010; Available from: http://www.ncceh.ca/content/drugs.

Access to Cooling Centers

Indicator Tittle: Distance to cooling center

Indicator Description: Distance from census tract to nearest cooling center

Assessment Group: Adaptive Capacity

Summary of evidence for climate and health:

Cooling centers are typically public spaces like libraries and community centers and are intended to provide air conditioning and a cool environment for people without access to air conditioning. Because air conditioning can decrease mortality, opening air-conditioned spaces can reduce adverse community health outcomes. During the 2011 heat wave, only 44% of people knew what a cooling center was and far fewer people visited one (Hayden et al 2017). The concept of a cooling center is a great idea, but only if the facilities are utilized.

What is the indicator: Distance in Miles to the nearest cooling center

Data Source and methodology: The distance to the nearest cooling center from each census tract centroid in terms of miles of road traveled. Cooling centers were those government facilities participating in the Beat the Heat program as of 2020. Network Analysis was used to get the distance in terms of miles of road traveled.

1. Calculate Centroid of Census Tracts
    a. Use Feature to Point analysis tool
        - Leave Inside Unchecked
2. Calculate Distance to Nearest Cooling Center
    a. Use Generate Near Table analysis tool
       (This creates a table with the distance information, avoid using the similar Near analysis tool because it modifies the initial cooling center layer)
        - Input Features set to Census Tract Centroids
        - Near Features set to Cooling Stations
        - Search Radius leave blank to consider all cooling stations

- Leave Checked boxes as Default (Find Only Closest Feature is the only one checked)
- Leave Method as Planar

b. The tool creates a Table with the linear distance in feet recorded in the NEAR_DIST column

3. Join the Near Table output to Census Tracts
   a. Join on Object ID for both the Table and the Census Tract Layer.
4. Save as Feature
   a. Joins are links between to separate features. Joined features cannot be edited, published, or easily moved/reused like full features can.
   b. Use the Copy Feature analysis tool
      - Input Features set to the joined Census Tract Layer
5. Calculate Distance in Miles
   a. Add Field to Copied Census Tract Layer
      - Set Data Type to Double
   b. Add Data to new field with Calculate Field
      - Divide NEAR_DIST by 5280 to get distance in miles

<u>With Network Analyst</u>

Set up Analysis Tools: Network Analyst -> Closest Facility

Import Facilities -> Cooling Centers

Import Incidents -> Census Tract Centroids

Finds Nearest Center from 'Incident' location in terms of time or distance, gives driving directions

Can set cutoffs so won't consider locations too far way

Limitations: This data only includes government operated cooling centers that are activated during an extreme heat event because these facilities are open to anyone. Often, movie theatres and malls are considered cooling spaces, however there may be complications that prevent certain populations from utilizing those spaces.

References:

Hayden, M. H. *et al.* Adaptive Capacity to Extreme Heat: Results from a Household Survey in Houston, Texas. *Weather. Clim. Soc.* **9,** 787–799 (2017).

Tree Canopy

Indicator Title: Tree canopy coverage

Indicator Description: Percentage of tree canopy coverage

Assessment Group: Adaptive Capacity

Summary of evidence for climate and health:

Tree Canopy provides natural shade and cooling during extreme heat events. Forested tracts break up the heat islands and reduce the temperature of surrounding areas. Shaded houses and buildings require less air conditioning to maintain a comfortable temperature. Shaded yards, sidewalks, parks and recreational areas allow for active use in conditions where it may otherwise have been too hot.

What is the indicator: Percentage of land area with tree canopy cover

Data Source and methodology: Tree Canopy data was obtained from the 2016 U.S. Geological Survey (USGS) National Land Cover Database (NLCD) at https://www.mrlc.gov/data/type/tree-canopy. The original 30 by 30-meter raster was converted to points and averaged by Census Tract.

Limitations:

References:

Marsha, A., Sain, S. R., Heaton, M. J., Monaghan, A. J., & Wilhelmi, O. V. (2018). Influences of climatic and population changes on heat-related mortality in Houston, Texas, USA. *Climatic Change*, *146*(3/4), 471–485. https://doi-org.hcpl.idm.ocl

Air Conditioning

Indicator Title: Household air conditioning

Indicator Description: Percentage of households without air conditioning

Assessment Group: Adaptive Capacity

Summary of evidence for climate and health:

Air conditioning is critically important because it can decrease exposure to extreme heat. Eliminating exposure to extreme heat eliminates the negative health outcomes from the hazard. In multiple U.S. studies, air conditioning has been shown to reduce heat-related mortality (Gronlund et al 2014). Thirteen percent of people living in Houston during the 2011 heat wave did not have air-conditioning (Hayden et al 2017). Residents without air conditioning or those limited by energy costs are at an increased risk of negative health outcomes, especially if they live in an urban heat island that does not adequately cool off at night.

What is the indicator: Percent of living units with Air Conditioning

Data Source and methodology: Air Conditioning estimates by census tract were calculated from publicly available HCAD data available at https://pdata.hcad.org/download/index.html. Data for this project were downloaded on May 29th, 2020 and filtered for residential buildings, apartments, and other living units using the methodology in Appendix A.

Limitations: The designation of AC capability is a contextual one as Harris County assessors can only note air conditioning units visible from the street. Presence of an air conditioner does not mean the air conditioner is working or being used. Electricity costs prevent some households from using the air conditioner.

References:

Gronlund, C.J. Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: a Review. *Curr Epidemiol Rep* **1,** 165–173 (2014). https://doi.org/10.1007/s40471-014-0014-4

Hayden, M. H. *et al.* Adaptive Capacity to Extreme Heat: Results from a Household Survey in Houston, Texas. *Weather. Clim. Soc.* **9,** 787–799 (2017).

Appendix A

❖ Required Data Files

- HCAD_Parcels_Centroid_5_29_20 – Centerpoint locations of all HCAD parcels, including lots, residential and commercial buildings (1,423,844 records), available in K/Workgroups/GIS/EPH/2020_Projects/EPH_20011_Climate_HCAD_05_18_20/Gdb/HCAD_05_18_20.gdb. Updated Parcel data is also available in the ITC Repository under hcitc_repository.SDE.Parcels and can be downloaded from https://pdata.hcad.org/GIS/

- Census Tracts Layer – There are many census tract layers available from the ITC and HCPH repositories. This project used 2010 census tracts.

- HCAD Parcel File Data – This data can be downloaded as text files from the HCAD website (https://pdata.hcad.org/download/index.html) and imported into any data management program. The raw text data files used in this project are listed below. They were downloaded on 05-18-2020 and saved in the project Tables folder at K:\GIS\EPH\2020_Projects\EPH_20011_Climate_HCAD_05_18_20\Tables\HCAD_2020\HCAD_05_18_20. They were also imported into the project file geodatabase at ~EPH_2011_Climate_HCAD_05_18_20\Gdb for use in ESRI mapping programs
    - Building_res.txt – all residential information (1,209,768 records)
    - Building_other.txt – information on all other buildings (152,097 records)
    - Structural_elem1.txt – structural information on single family, multi family, condos, town homes Home information (CDU, Grade Adjustment, Physical Condition) (8,037,434 records)
    - Structural_elem2.txt – structural information on commercial buildings (1,484,221 records)

PART 1: DATA PREP

1. Accessing HCAD Parcel File Data

- These tables are too large to use in Excel. While the data can be manipulated in ESRI programs, I found ArcGIS Pro to be too slow. Potential data management programs are Access, Microsoft SQL Server Management Studio, R Studio, or a python IDE. Directions for importing the data into Access are given on the HCAD website. I used R and R Studio.

- R and R studio are freely available at https://www.r-project.org/ and https://rstudio.com/products/rstudio/download/ and do not need administrative permissions to install if installed in one of your personal folders. Steps are described for use in any program, but code is limited to R and SQL. The complete R script file is HCAD_Data.R in the project documents file (~EPH_2011_Climate_HCAD_05_18_20\Docs). Once one installs R and R studio, they can open this file and run the code on the updated text files without having to alter anything.

- The raw text files are Tab delimited and lack column names. Column names are available in the Access shell and through a link on the HCAD website. (https://pdata.hcad.org/DB/Pdata_Fieldnames.pdf). The data used in this project have already been imported into the Access file located at ~\EPH_20011_Climate_HCAD_05_18_20\Tables\HCAD_2020\HCAD_05_18_20

2. Merge Residential and Commercial Data together

- Residential buildings in Apartment Complexes, Nursing Homes, and College Campuses among others are considered commercial and are not included in the residential dataset.

- Merge building_res and building_other
  - These tables have different columns. Select ACCOUNT, USE_CODE, BUILDING_NUMBER, IMPROV_TYPE, BUILDING_STYLE_CODE, and PERCENT_COMPLETE from both tables.
  - Note the column names for Building Number and Improvement Type don't match and will need to be changed so they do.
  - The merged tables were saved as 'building'

In R Studio:

```
library(dplyr)
res <- building_res  %>% select(ACCOUNT, USE_CODE, BUILDING_NUMBER,
IMPRV_TYPE, BUILDING_STYLE_CODE, PERCENT_COMPLETE)
 names(res)[4] <- "IMPROV_TYPE"

other <- building_other %>% select(ACCOUNT, USE_CODE, BLD_NUM, IMPROV_TYPE,
BUILDING_STYLE_CODE, PERCENT_COMPLETE)
 names(other)[3] <- "BUILDING_NUMBER"


building <- rbind(res, other)
```

- Merge Structural_elem1 and Structural_elem2
  - These tables have matching columns and can be merged directly
  - The merged tables were saved as 'Structural_elem'

In R Studio:

```
structural_elem <- rbind(structural_elem1, structural_elem2)

structural_elem$Building_ID <- paste(structural_elem$ACCOUNT,
   structural_elem$BUILDING_NUMBER, sep = "_")
```

3. Select out Residential Data

- In the HCAD building datasets the ACCOUNT number is the unique ID for a particular parcel of land that may have any number of buildings or uses. The Building_Number is an ID for each separate building on that parcel. Each row represents one building on a parcel, therefore a parcel with 3 buildings will have 3 rows, all with the same account number and building numbers of 1 to 3. A new field, 'Building_ID' was created by combining the account and building numbers.

- The Improvement Type is a generic description of the parcel, it can be Residential Single Family, Mobile Home Park, Nursing Home, etc. The Building Style Description is more specific to the building, for example a parcel with a house might have an Improvement Type of Residential Single Family and a Building Style Code of Residential 1 Family for the house and Residential Garage – Detached for their garage, each on their own row.

- This Project identified 22 Improvement Types and 39 Building Style Codes to include as residential housing. This definition includes long-term residents of nursing homes, retirement homes, rooming houses, and dormitories. To be included a record needs to have both its Improvement Type and Building Style Code match one of the identified codes. Tables 1 and 2 in the Appendix contain descriptions of all the identified codes. Additionally, only buildings that were fully complete were included to avoid counting buildings under construction.

- This table was saved as 'homes' in R Studio:

```
library(dplyr)
home_improv <- c(1001, 1002, 1003, 1004, 1005, 1006, 1007, 1008, 1025, 4201, 4209, 4211,
4212, 4213, 4214, 4221, 4222,4313, 4316, 4317, 4318, 4319)

home_desc <- c(101, 102, 103, 104, 105, 106, 107, 108, 109, 125, 8177, 8178, 8179, 8300, 8313,
8321, 8324,8330, 8351, 8352, 8354, 8401, 8424, 8451, 8459, 8546,8547,8548, 8549, 8550, 8551,
8589, 8710, 8984, 8986, 8987, 8988, 8989, 9351)

homes <- building %>% filter(IMPROV_TYPE %in% home_improv & BUILDING_STYLE_CODE %in%
home_desc & PERCENT_COMPLETE == 1.00) %>% arrange(ACCOUNT, BUILDING_NUMBER)
homes$Building_ID <- paste(homes$ACCOUNT, homes$BUILDING_NUMBER, sep = "_")
```

4. Select out Air Conditioning Data

- Each row in the structural element tables refers to a characteristic of a building identified by Account and Building Number. Each Building has about 4 -10 structural elements listed. The characteristic in question is identified by the column 'STRUCTURE_TYPE' and the column 'CATEGORY_DESCRIPTION' includes the information about the structure type.

- Structure Types Central Heat / AC (HAC) and Cooling Type (CLG) were identified as pertaining to Air Conditioning. Category Descriptions for these structure types were: Central Heat / AC, Central Heat, A/C Only, Central Forced, Non-window Unit, and None.

- Buildings with Category Descriptions of None and Central Heat were defined as not having air conditioning, buildings with all other Category Descriptions were defined as having air conditioning and buildings missing this information were excluded from consideration.

- Created the new column of AC - Buildings that met the criteria for having Air Conditioning were given an AC value of 1, indicating TRUE, and buildings that met the criteria for not having Air Conditioning were given an AC value of 0 for FALSE. Some buildings had duplicate records and for this project 1,822 buildings had records that indicated it both did and did not have Air Conditioning. These were removed.

In R Studio:

```
structural_elem_AC <- structural_elem %>% filter(STRUCTURE_TYPE == "CLG" |
STRUCTURE_TYPE ==   "HAC")

structural_elem_YesAC <- structural_elem_AC %>% filter(CATEGORY_DESCRIPTION != "None" &
CATEGORY_DESCRIPTION != "Central Heat")

structural_elem_NoAC <- structural_elem_AC %>% filter(CATEGORY_DESCRIPTION == "None" |
CATEGORY_DESCRIPTION == "Central Heat")

YesAC <- structural_elem_YesAC %>% summarise(Building_ID = unique(Building_ID), AC = 1)
NoAC <- structural_elem_NoAC %>% summarise(Building_ID = unique(Building_ID), AC =  0)
AC <- rbind(YesAC, NoAC)
AC_NoDup <- AC[!duplicated(AC$Building_ID), ]
```

5. Merge AC Data to Homes and Export to csv

- The new AC column was added to the homes residential table, according to Building ID. Only 125 homes did not have a match. These were considered unknown and dropped from further analysis.
- The csv file will be too large to open fully in Excel. However, all of the records will be saved appropriately and will show up when the file is imported into ArcGIS Pro.

In R Studio:

```
homes_final <- merge(homes, AC_NoDup, by = "Building_ID")

write.csv(homes_final, file = "K:\\Workgroups\\GIS\\EPH\\2020_Projects\\
                                EPH_20002_Climate\\Tables\\HCAD_homes_AC.csv")
```

PART 2: MAP IN ESRI

1. Load data into Arc GIS Pro
   - Add the HCAD_Parcels_Centroid_5_29_2020 described in Required Data Files

- Add a Census Tract file from the ITC Repository
- Add the homes_final csv file from Part 1

2. Join homes_final to HCAD Parcel Centroids by Account Number
    - Make sure the Field types for both Account Numbers match – the one for HCAD Parcels is a text field and the one from homes_final will likely be imported as numeric.
    - ArcGIS does not let you change field data types. You will need to create a new column of the appropriate data type and copy the data over. You will also need to save one or the other files locally with Copy Features before you are allowed to add a column.
    - Also, if you are using the text field type make sure the leading zeros from the homes_final account numbers were not dropped. All account numbers should be 13 characters long.
3. Save the Join as a new feature Layer
    - This step may be skipped if you have a fast computer. Selecting records straight from the Joined table in my surface pro resulted in a very long computation without a progress bar that resembled a frozen program.
    - Using Copy Features to save the joined feature layer may or may not be faster, but at least you will have a progress bar the entire time.
    - This layer was saved as HCAD_Parcels_Centroid_5_29_20_AC_jn
4. Select out buildings with AC data
    - Use Select by Attributes with the expression Where AC is not null and make a new layer from the selected features, now you have locations for all of your homes.
    - Make this selection its own layer or go straight to the next step with the selection active, the tool will only include the selected records
5. Intersect with Census Tracts Layer
    - Use the Intersect Analysis Tool on the HCAD_Parcels selection and Census Tracts layers to identify the census tract for each home. The tool will create a new layer showing the HCAD Parcel locations with the ID number of the census tract added to its Attribute Table.
    - This layer was saved as HCAD_Parcels_AC_int
6. Summarize intersect layer, summing AC column
    - Open the Attribute Table of your intersect layer and summarize. Make sure the Case Field is the FID Census Tract ID, select AC for your Statistics Field and Sum for your Statistic Type.
    - This will create a Standalone Table with the number of homes per census tract (Frequency) and the number of homes with AC (SUM_AC).
    - This table was saved as HCAD_Parcels_AC_int_Summary
7. Calculate the Percent AC
    - Create a new field for Percent AC in the summary table and use Calculate Field to populate it
8. Join back to census tracts layer
    - Join the summary table to the Census Tract layer by the FID ID in the summary table and the ID in the census tract layer

- Use Copy Features to save the final product
- This feature was saved as HC_CensusTracts_2010_AC

Table 1. Building Type Codes

BuildingTypeCode	BuildingTypeDescription
1001	Residential Single Family
1002	Residential Duplex
1003	Residential Triplex
1004	Residential Fourplex
1005	Mixed Residential / Commercial
1006	Residential Condo
1007	Residential Townhome
1008	Residential Mobile Homes
1025	Farm Single Family Dwelling
4201	Residential Structure
4209	Apartment Struct. 4-20 Units
4211	Apartment Garden (1 to 3 Stories)
4212	Apartment Mid Rise (4 to 11 Stories)
4213	Mobile Home Park
4214	Apartment High Rise (12 stories and above)
4221	Subsidized Housing
4222	Apartment - Tax Credit
4313	Dormitory
4316	Nursing Home
4317	Retirement Home
4318	Boarding & Rooming House
4319	Commercial Bldg. - Mixed Res.

Table 2. Building Style Codes

BuildingStyleCode	BuildingStyleDescription
101	Residential 1 Family
102	Residential 2 Family
103	Residential 3 Family
104	Residential 4 Family or More
105	Mixed Res/Com, Res Structure
106	Condominium (Common Element)

107	Townhome (with Common Element)
108	Single Wide Residential Mobile Home
109	Double Wide Residential Mobile Home
125	Farm with Dwelling
8177	Townhouse, High-rise - End Unit
8178	Townhouse, High-rise - Inside Unit
8179	Townhouse, High-rise - Detached
8300	Apartment
8313	Convalescent Hospital
8321	Dormitory
8324	Fraternity House
8330	Home For The Elderly
8351	Single-Family Residence
8352	Multiple Res (Low Rise)
8354	Townhouse Inside Unit
8401	Townhouse, End Unit
8424	Group Care Home
8451	Multiple Res. (Sen. Citizen)
8459	Mixed Retail w/ Resid. Units
8546	Senior Citizen Townhouse, End Unit
8547	Senior Citizen Townhouse, Inside Unit
8548	Urban Row House, Detached
8549	Urban Row House, End Unit
8550	Urban Row House, Inside Unit
8551	Rooming House
8589	Elderly Assist. Multi. Res.
8710	Retirement Community Complex
8984	Luxury Apartment
8986	Int. Space, Townhouse, Inside Unit
8987	Int. Space, Multiple Resid.
8988	Int. Space, Townhouse, End Unit
8989	Int. Space, Apartment
9351	Single-Family Residence